1075 Issued May 4, 1908.

PORTO RICO AGRICULTURAL EXPERIMENT STATION.

D. W. MAY, Special Agent in Charge.

ANNUAL REPORT

OF THE

PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1907.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1908.

1075 Issued May 4, 1908.

PORTO RICO AGRICULTURAL EXPERIMENT STATION.

D. W. MAY, Special Agent in Charge.

ANNUAL REPORT

OF THE

PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1907.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1908.

PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, Chief of Division of Insular Stations, Office of Experiment Stations.

STATION STAFF.

D. W. MAY, *Special Agent in Charge and Animal Husbandman.*
J. W. VAN LEENHOFF, *Coffee Expert.*
W. V. TOWER, *Entomologist and Plant Pathologist.*
M. J. IORNS, *Horticulturist.*
OSCAR LOEW, *Physiologist.*
P. L. GILE, *Assistant Chemist.*
E. F. CURT, *Farm Superintendent.*
CARMELO ALEMAR, Jr., *Stenographer.*

LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., January 20, 1908.

SIR: I have the honor to transmit herewith and recommend for publication the Annual Report of the Porto Rico Agricultural Experiment Station for the fiscal year 1907.

Respectfully,

D. W. MAY,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

ANNUAL REPORT OF THE PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1907

SUMMARY OF INVESTIGATIONS.

By D. W. May, *Special Agent in Charge.*

INTRODUCTION.

The fiscal year 1906–7 has been a prosperous one for Porto Rico, in agricultural lines especially. The total import and export trade of the island for the year was $45,000,000. The exports included in this sum totaled $23,257,530. This represents agricultural produce, very largely in a raw state. The exports of the island show a large annual increase since the year 1901, the exports that year aggregating $8,583,967. The total sum for the year 1906 of both exports and imports and of each separately aggregate almost double the amount of any year in the previous history of the island. As many of the leading agricultural resources of Porto Rico, like the citrus industry, are only beginning, an increase in agricultural production may be expected to continue for years to come unless some very untoward calamity occurs.

The people of Porto Rico are studying as never before the resources of their country and the possibilities of the soil and climate. Credit must also be given to the many planters from the States who are investing their means and building homes in Porto Rico. The increase in land values is caused by the increased values produced by our soils under the improved methods that are being followed. Porto Rico is at the door of the markets of the large cities of the eastern United States, the best market in the world, with a low freight rate and no duty to pay. Her prosperity then should depend upon her own efforts and be measured by her industry.

The striking difference in the new agriculture of Porto Rico is the diversity of her crops. In the times of Spain coffee and sugar were the great staples, while no effort was made to grow even articles of universal need that were easily adapted to the soil and climate. This is still in evidence, as shown by the enormous importation of rice, as well as many of the common vegetables. However, some articles that were imports are now in the list of exports and the number will be further increased.

Besides a continuation of the work of the agricultural experiment station previously reported, several new lines have been planned and put into effect. This has been made possible by the Congress of the United States providing additional funds for maintenance, which for the coming year amount to $9,000. Out of this sum a chemical laboratory is being fitted up and a chemist and assistant chemist have been employed. It is hoped also to add a plant pathologist to the staff, permitting the entomologist to devote all his time to that subject.

The present greatest need of the station is a suitable building for carrying on the work of its various departments. Heretofore an abandoned sugar mill that stood on the plantation when purchased for the use of the station has been employed for this purpose, but it is wholly unsuited to the requirements. A modern building situated on higher ground, with a system of ventilation and adapted to bacteriological and chemical work, is much needed. In fact, it is absolutely required before certain work now necessary can be carried further.

During the year H. C. Henricksen, horticulturist of the station, resigned to enter other service. He was succeeded by M. J. Iorns, Ph. D., of Cornell University. Dr. Oscar Loew, formerly connected with the U. S. Department of Agriculture and lately with the Imperial University of Tokio, Japan, was appointed chemist. P. L. Gile, A. B., of Harvard University, was appointed assistant chemist.

The experimental work of the station, which will be reported under separate heads and by the different departments, has been increased and extended. The tree fruits planted soon after the station was established are coming into bearing, and a number of these have been found commercially adapted to Porto Rico. In the agricultural development of the island certain crops have increased enormously, while others that have been found successful in an experimental way are being taken up commercially by various planters in different sections of the island.

SUGAR CANE.

Of the exports of Porto Rico, sugar is largely in the lead, aggregating during the fiscal year, $14,738,572. This is over $5,000,000 in excess of all other exports. The area devoted to sugar cane will doubtless increase somewhat for several years. The production per acre, however, is likely to show a considerable increase. This is by reason of the fact that not only are better methods of cultivation being practiced, but canes carrying a higher percentage of sucrose in the juice are being planted. The experiment station has a number of seedling canes in the experimental plats which contain from 15 per cent to 19 per cent of sucrose in the juice. The average percentage of cane now grown in Porto Rico is much below this, possibly aver-

aging around 10 per cent. These seedling canes are being sent out from time to time to different planters over the island for trial. Some are found best adapted to certain sections, while others seem superior on other soils or under different climatic conditions. The breeding of new canes is proving of great benefit to the island. Not only is the yield of sugar greatly increased by some of the new varieties, but their general thriftiness is greater and resistance to disease stronger. The largest sugar company on the island has recently employed two men to work in cooperation with the station in the breeding and disseminating of new canes.

In experiments in fertilizing cane at the station the great lack seems to be in the nitrogen content of the soil. With heavy rains and burning sun nitrogen is rapidly eliminated from the fields. On the other hand, various legumes flourish in Porto Rico and nitrogen can doubtless be grown even in connection with continuous cane culture. Owing to the profitableness of the sugar cane, Porto Rican planters employ every means to take this crop year after year from the same land. As nitrogen is by far the most expensive element of the fertilizer and apparently the one most needed, experiments are being carried out with a view of demonstrating the feasibility of supplying this element in the cane fields by the growing of leguminous crops between the rows. Of the legumes being tested, the cowpea and the sword bean are the most promising, but several years experimenting will be necessary to determine the value of the system of growing these crops on the same ground with cane. The cowpea will mature in seventy days, so that a crop can be readily grown between the rows after planting the cane and again after the last plowing.

Experiments with distances of planting in cane production are being carried on for the purpose of determining the method that will give the most cane per acre at the least cost of production. The usual practice in the island is to plant very close, 5 by 6 feet. The station's experiments have been carried on with hill planting 5 by 5 feet up to 10 by 10 feet, and also in continuous rows. For the first crop the narrow planting has given the heaviest yield. As only one crop has been harvested from these plats, figures on the rattoon crops can not be given, but the indications are that the differences in yield will be less between the wide and narrow plantings on the second crop. As the cane is an intensive crop it seems advisable to grow as much as possible each year on the same area, supplying the drafts on the soil by the application of suitable fertilizers, and avoid thereby the necessity of leaving the lands idle for a series of years to recuperate. In proportion to the development above ground the root system of the cane plant is not extensive, therefore very heavy tonnage can be taken from a small area. Our cane growers can derive great benefit from

thorough preparation of the soil before planting. Agriculture in Porto Rico has only skimmed the surface, plowing being very shallow and often with only a wooden plow. Some of the large sugar companies have put in steam plows, which are going to a depth of 8 inches or more. This is found a very profitable practice, giving large profits for the cost of the work. After the canes are planted more thorough cultivation of the surface should be given than is usually practiced. A great deal of hand labor should be supplanted with the cultivator for reasons of economy.

In planting cane it is a better practice to open furrows with the plow, it being less expensive than cutting holes with spades, as is usually done. Moreover, by this method the ground is stirred to a greater depth and a larger surface is pulverized. From preliminary experiments at the station continuous rows have given larger yields than the same number of canes planted in squares. In planting in rows canes were stuck in the ground on end, as is the usual custom. The Hawaiian system of planting the canes in lines covered entirely with earth has also been followed. This is a better practice where the changa, or mole cricket, is not too bad. Where this insect is prevalent, however, the young seedlings are liable to be cut off when they break through the ground. If the canes are planted entirely below the surface, the young seedlings will doubtless get more nourishment from them than when planted on end. Again, when planted on end the ants carry off considerable of the juice of the cutting and some of it is lost by drying out and rotting above the ground. From the one crop of plant cane the Hawaiian system gave more tonnage than the similar plats planted in the native fashion, although by the former method a small portion had to be replanted because of the ravages of the changa.

Fertilizing canes in Porto Rico will pay in nearly all cases but, owing to the variations in the soil, it is impossible to give any definite plan. The fertilizer should be applied early, and it is especially advisable to start the canes off with a readily available fertilizer. An early start and a strong one means a great deal to the cane plant. It will make a larger growth and also be able to assimilate more of the elements already in the soil if it can get a quick start. Further details of fertilizing are to be found in Circular No. 6 of this station, recently issued.

COFFEE.

The exports of coffee from Porto Rico for the fiscal year aggregated $3,496,082. Of this amount the United States purchased only a little over 1 per cent. While practically all of the sugar went to the United States comparatively little of the coffee was sent there. This is for two reasons: (1) The duty on sugar makes the United

FIG. 1.—PREANGER COFFEE PLANTED ACCORDING TO EAST INDIAN METHOD.

FIG. 2.—TYPICAL COFFEE PLANTATION IN INTERIOR OF PORTO RICO.

States its natural market, and (2) there is no duty on coffee, and the American people do not relish the peculiar flavor of our variety. Porto Rican coffee is a very fine after-dinner coffee much relished in the Latin countries of Europe, and most of our exports of coffee find their market there. Efforts have been made to introduce Porto Rican coffee into the United States, but so far little progress has been made in this direction. It is very hard to change the taste of a people. It were better, if such a market is desired, to produce the coffee which already has an established trade with the States and which brings the highest price in that market. With this in view, the experiment station is carrying on experiments in growing the higher-priced Java coffees, which are highly flavored and command the highest prices in the States. (Pl. I, fig. 1.) From the few berries which have matured to date, it seems probable that highly flavored coffees can be grown in Porto Rico and retain the aroma peculiar to them in the countries from which they are now shipped. Whether they will continue to do so year after year is a matter for further experiment. More details of the experimental work with coffee are given in the report of the agent and expert in charge (p. 39).

Some coffee is being planted in the interior, but the extension of the industry in the island is very small and the outlook is not encouraging for the future. (Pl. I, fig. 2.) The enormous production of coffee by Brazil is not very favorable for prices of this product in the world. From statistics it appears that there is a great deal of coffee on hand in the markets, and while the Brazilian Government is holding a great deal of it with the hope of maintaining the price, unless the world's production is curtailed the price will be lower.

In some of the old coffee plantations in Porto Rico orange trees are being planted. Others are being cleared out entirely and the land devoted to pineapples and tobacco. As a rule, inaccessible lands in the interior are being planted to coffee, while the old plantations, especially where they are near the macadamized roads, are being planted to more remunerative crops. Better planting and cultivation would doubtless increase the yield of coffee. Fertilization can also be profitably practiced in some instances, especially where large deposits of bat guano are found near by. As the profits from this crop are small, planters are not inclined to expend much in commercial fertilizer. This is especially true where the means of transportation are difficult.

TOBACCO.

The tobacco crop during the past year was not as successful as that of the preceding year. This was due largely to an unfavorable season, resulting in great losses in the seed beds, which was followed by the setting of inferior plants from any source available. Altogether

the entire season was unfavorable to the production of a crop of high quality. However, the extension of this industry is shown by the crop of the coming year. A more detailed report on the handling of the crop, the curing, and fermentation is given in another section of this report (p. 16).

FIBER CROPS.

The station is continuing the experiments with various fiber crops, as described in former reports. From all considerations of soil and climate sisal seems to be the most promising. A great deal of land that is not adapted to any other purpose is suitable for the production of this fiber. With an appropriation made by the insular government the station purchased 100,000 plants and a number of them have since been sold to planters at $15 per thousand. This sum, while very low, covers the cost of handling the plants. It is to be hoped that more lands will be set to sisal, especially the dry limestone sections that are not profitably employed in growing any other crop. The abacá or Manila hemp also grows well on the island, but requires a fertile soil such as will grow bananas. The extension of abacá cultivation is therefore not expected, as land suitable for it can be more profitably employed in growing other plants.

During the year a number of plants of Carludovica have been imported from Guayaquil, Ecuador, for introduction as a hat fiber. It is from this plant that the genuine Panama hat is made, and it is our purpose to extend its planting among our hat weavers. Besides producing many hats from a native palm, several factories are turning out genuine Panama hats, all made, however, from imported fiber.

COTTON.

Sea Island cotton is produced in some amount in different sections of the island, but there is little if any increase shown over that of the previous year. Porto Rican planters are hard to interest in cotton growing. This is due mainly to the fact that they do not understand the best methods employed in its culture. The land must be fertilized for cotton and the planter must be prepared to protect this crop from the ravages of insects, especially the cotton caterpillar, which sometimes comes in immense armies. Unless the cotton grower is prepared with a good supply of pure Paris green, his crop is liable to be swept away very quickly.

FORAGE CROPS.

Guinea and malojillo grass continue to yield the forage largely consumed in the island. It is advisable to grow other forage crops that are rich in protein in order to give a more balanced ration. For this purpose cowpeas and velvet beans have succeeded best at the station.

Alfalfa grows, but it requires constant cultivation to keep it from being choked out by the vigorous native grasses. Alfalfa might succeed better, however, in the drier sections of the island, notably on the black soils on the south side.

FORESTRY.

There exist in Porto Rico, between the low lands devoted to sugar cane and the high lands devoted to coffee, many foothills bare of trees. These lands are not very productive, yielding for the most part scanty pasturage. Many of these low-lying hills are excellent orange lands. They were formerly covered with forests which have been utterly destroyed. Owing to the heavy rains and baking sun it is a difficult matter to get these lands again set to trees. In our experiments on a very tenacious red clay hill many native and introduced species of trees have been planted. With the exception of species of Eucalyptus no satisfactory growth has been made. Of the others the leguminous species have done best.

Nature in reforesting sends up first a straggling growth of brush, which after growing for some years affords a shelter for seedlings of larger growth. It appears best, therefore, in reforesting such areas to grow at first hardy shrubs or trees like the guava, with a view of getting the ground covered with a protective crop and later planting it to the more valuable forest trees. Such a system, however, must look to the future for returns. As shown in another portion of this report, wind-breaks are necessary in the production of citrus fruits, and this is also essential with many other economic trees. Therefore, on the bare, wind-swept hills of Porto Rico reforesting with hardy trees is essential in bringing them into a condition to grow economic trees and tree fruits.

FERTILIZERS.

The soil of Porto Rico is naturally productive, but in many sections for a long time agriculture has been carried out with the object of getting continuous crops from the soil without returning anything thereto. It is not strange, therefore, that many of the lands are unproductive. However, the soils respond very readily to applications of manures and fertilizers, most of them needing the three elements—nitrogen, phosphorus, and potash. The imports of fertilizers for several years have greatly increased. The planters are finding out the value of proper fertilizers, and they are urged by the experiment station to apply such in their operations. In hardly any line of agricultural endeavor in the island can the greatest success be obtained without the application of fertilizers.

A fertilizer law which will cover the importation and the sale of all artificial manures is needed very much. Such a law was passed

three years ago by the legislature. This act was drawn up by members of the experiment station staff and was modeled on the Georgia law. It carried an expense of 25 cents per ton for its enforcement. Pressure was brought to bear on the legislature at the succeeding session by certain large interests and dealers to have cut out the clause providing for the enforcement of the law. The act now remains a dead letter and the consumer is without adequate protection in the purchase of fertilizers. In view of this fact, many of our planters are buying the ingredients and mixing their own goods. Regardless of the fact that they may sometimes buy a mixed fertilizer to advantage, they are led to the latter course because they have absolutely no protection in the matter.

The station advises planters to use as far as possible the supplies of stable manure and the bat guanos found in many sections of the island. Many analyses have been made and home-made fertilizers planned, thereby saving a great deal of money to the plantation owners.

LIVE STOCK.

The exports of live stock have been on the decline for several years, while the average value in the island has greatly increased. As agricultural industries extend and the country becomes more prosperous the demand for animals naturally grows. Some improvements in the horses by the selection of sires and by the importation of breeding stock from the States are noted. Horses with due care can be acclimated, and the Porto Rican horse adapts itself very readily to improvement by crossing with the lighter types of horses from the States, as the standard-bred or the American saddle-bred horse. The native horse is one of great stamina and some are quite handsome. They should, however, be bred for greater size. The average price of horses in Porto Rico has more than doubled in the past few years. Some planters are going in for horse and mule breeding with every assurance of success. A great many mules have been imported into the island during the year for working in the cane and tobacco plantations. Also some jacks and jennets for breeding purposes. Mules are well adapted to the work in Porto Rico and stand the climate very well.

CATTLE.

Formerly large numbers of cattle were exported, principally to Cuba for work in the cane fields. This trade has fallen off to less than half since 1901. The consumption of meat on the island has doubtless grown with the increased prosperity, and the extension of the sugar-cane planting has taken a great many cattle for working purposes. In Porto Rico cattle are considered first as beasts of burden, and they have been selected and bred with the object of producing work animals. Now mules are supplanting cattle to a certain

extent, while meat and milk products have increased in value. To help supply the latter products cold-storage meats and tinned milk, cream, and butter are imported from the States. Porto Rican cattle have a splendid physique, and by selecting and breeding with a definite end in view doubtless earlier maturity could be obtained and the milking function greatly increased. It is a question whether it is best for a planter to improve his cattle by careful selection of native stock or by the importation of improved breeds. If the tick fever occurs on the island it is in a mild form and cattle can become acclimated without severe losses where due care is practiced. On the other hand, the ticks are very fond of the long-haired imported cattle, and it takes constant and unremitting care to keep these insects from sucking the blood to such an extent as to produce an emaciated condition in such animals. If pure-bred cattle are brought into the island the importer should be prepared to give them the very best of feed and attention and to keep them at all times comparatively free from ticks. Unless the importer is prepared to give imported cattle good stabling, feed, and water, and grooming and cleaning from ticks, he had better not bring them to Porto Rico.

Herds can probably be improved in the safest way by the importation of bulls for crossing on native cows. There are a number of crossbred animals on the island that show improved formation and probably earlier maturity by reason of the cross.

PIGS AND POULTRY.

Improved breeds of pigs brought into the island have done well where they have received proper care. Disease is very rare among this class of live stock in Porto Rico. The method of handling these animals in the island is capable of much improvement. They are usually staked out near the dwelling of the owner and their feed is insufficient. Pigs more than any other class of domestic animals thrive best with a variety of food and especially require grass. With fenced lots and at large pigs will thrive much better than where confined with ropes.

The prices of poultry and eggs have been on the increase in Porto Rico during the past year. All classes of poultry stand in need of improvement by the importation of the better producing breeds. Poultry will thrive in all sections of the island with due care, but should be allowed freedom of range, should not be crowded, and should have some feed when grown in any numbers.

No serious epidemic diseases have been noted at the experiment station with chickens, ducks, geese, and turkeys. A disease producing lumps on the comb and at the base of the bill on chickens has been noticed. This seems to be a bacterial growth. Washing the heads of the fowls with a saturated solution of boracic acid gave relief.

REPORT OF THE PHYSIOLOGIST.

By Oscar Loew.

FERMENTATION OF TOBACCO.

Curing,[a] as well as fermentation, is not so carefully conducted in Porto Rico as in the United States. The high temperature prevailing in Porto Rico, even until late in autumn, enhances, of course, the chemical changes characteristic of these operations. The fermentation in bulk is sometimes carried out in open houses without any steam jets and other contrivances found, for example, in the Florida fermenting houses. In one case observed in Mayaguez the temperature of the bulks reached only 44.5° C. when the bulks were repiled. In Florida, however, the bulks are taken apart and built up again when the temperature has reached 55° or 56° C., or about 132° F. This building up of the bulk is done five to six and even eight times. Thus the eggs of certain small beetles are killed before they can develop the insects which often damage the manufactured cigar.

There is no doubt that the so-called after-fermentation of tobacco proceeds much more energetically in the continuously warm climate of Porto Rico than in the United States. Hence, it seems unnecessary in case of the main fermentation to turn over the bulks of tobacco quite so often as in the States. The temperature of 55° or 56° C. should, however, be reached in each bulk the first time.

Mr. L. Du Bois, field manager of a large tobacco company, has carried on selection experiments with tobacco for several years. He mentioned to the writer the interesting fact that at one time a lot of tobacco selected from Porto Rico seed did not flower for two years and continued growth and development of leaves until a height of 14 feet was reached. The plants were afterwards lost by accident.

DISEASES OF TOBACCO.

As to diseases of tobacco, Mr. Harrison Johnson, a tobacco grower of Cáguas, stated that in his opinion the various troubles observed in the United States occur more or less in Porto Rico. The mosaic disease or calico, however, seems not to occur generally. Mr. Du Bois, of Cáguas, with many years of experience, also stated that mosaic disease was never observed on his plantation. But this disease has

[a] The curing barns are usually exceedingly primitive huts.

FIG. 1.—TOBACCO GROWING UNDER CHEESE-CLOTH SHADE NEAR CAYEY.

FIG. 2.—TYPICAL PORTO RICAN WIND-SWEPT ORANGE ORCHARD.

attacked tobacco plants near the experiment station. The wilt disease was observed only once, according to Mr. Du Bois. He also mentioned a trouble observed with the tobacco of a certain section of the Aibonito district. This tobacco, several weeks after its fermentation, acquires such a disagreeable odor that it becomes worthless. Some of this tobacco was procured through Mr. Frese, in charge of the tobacco depots in San Juan. The odor was moldy or musty, the veins were covered here and there with a white mass, and many of the stems were so rotten that they easily broke into fragments on being handled. The microscopical examination revealed no fungus mycelium, but numerous bacteria, especially cocci, as well as yeast-like cells, belonging probably to a kind of Torula. This disease resembles pole-burn. Various hypotheses as to the peculiar inclination of the tobacco of this district to the disease might be suggested, but without further examination it would be useless. Cottonseed meal had been applied as fertilizer for a number of years on the affected fields.

A peculiar disease, spreading from a center in ring-like progression, was observed in the tobacco seed beds of Cáguas. The circle of dead, bleached seedlings increased continuously and could be checked only by removing the soil to some depth and treating the spot with diluted formaldehyde (1 spoonful to 30 gallons of water). The disease is called "sancochado" in Porto Rico. On microscopical examination no mycelium of fungi was discovered, but numerous very lively nematodes were found which doubtless cause the disease.[a] Mr. Du Bois has introduced a new system for avoiding the diseases of the seed bed, by transplanting the young seedlings into a second seed bed before they are set in the field. No top-dressing with nitrate is carried on.

The tobacco flea-beetle and the changa are considered the worst enemies of tobacco in Porto Rico. Most of the other insect pests of the field, especially the dangerous "cutworm," are avoided in growing the tobacco under cheese-cloth. (Pl. II, fig. 1.)

The tobacco of Porto Rico after fermenting is baled, and the numerous bales are then stored above and beside each other, resulting in a sort of after-fermentation in bulk. Since this may finally lead to loss of aroma by the fermentation going too far, the bales of tobacco are now also made up in some establishments in leaves of the royal palm (piraguas) instead of in the porous burlap, which admits too much air. The baled tobacco in a warehouse in San Juan showed last year much damage by mold fungi. It may also be mentioned

[a] Mr. Tower, entomologist of the station, has also observed tobacco plants in full development near this station killed by nematodes. The roots showed many and irregular swellings.

that according to Mr. Du Bois the wrapper leaves grown under cheese-cloth when held toward the light often show green spots after the fermentation. This trouble will be examined as soon as occasion offers.

NOTES ON THE AVOCADO FRUIT.

The avocado or aguacate is the pear-shaped fruit of several kinds of Persea, a tree of Central and South America. This fruit, weighing from 300 to 400 grams, has a green to yellow skin, measures 10 to 11 centimeters in length, has a very large and globular kernel of 5.5 centimeters in diameter and a soft flesh of butter-like consistency surrounding the kernel to a thickness of 1.4 to 1.6 centimeters. The kernel, weighing from 90 to 95 grams, contains starch and oil, also some tannin; a freshly cut surface rapidly assumes a red color in contact with the air, probably on account of an oxidation of a peculiar compound. The seed is rather hard, but when boiled it softens and is then said to be readily eaten by hogs. The taste of the kernel resembles that of the horse chestnut. There is no flavor and hardly any taste to this part of the fruit.

The flesh shows on microscopical examination numerous oil droplets in the cells, while starch granules are absent, at least in the ripened state. Carbohydrates are represented by small amounts of cane sugar, invert sugar, and slimy substance. The oil obtained on extraction with ether proves to be of superior quality and might rival olive oil, should it be present in large amount and cheaply obtainable. Simple pressure would yield only a part of it, and this is rendered impracticable on account of the slimy substance present. Extraction with bisulphid of carbon might be too expensive in consideration of the rather low percentage, and a simple heating or frying process would impair the fine quality.

Many valuable data in regard to varieties of avocado, its culture, cost of production, etc., have been published by the U. S. Department of Agriculture.[a] According to some chemical data published by the Department the flesh of the fruit contains 1 to 2.2 per cent protein and 10 to 17 per cent oil.

The fruit would no doubt find a market in the States if it would keep. Repeated shipments to New York have proved failures on account of decay of the fruits, believed to be caused by injuries to the skin, permitting the entrance of fungi. According to our own observations, however, every fruit, even with healthy uninjured skin and stem still attached, will gradually decay; that is, the skin will become brown and the flesh soft and sour. This process is analogous to the brown, mushy change often observed with certain varieties of pears. It commences at the core and proceeds outward until the entire fruit

[a] U. S. Dept. Agr., Bureau of Plant Industry Bul. 77.

has softened and become brown. It is due to the dying off of the cells, caused either by insufficiency of oxygen or accumulation of carbon dioxid in the cells, whereupon some enzyms stored up in the protoplasm of the cells become liberated and act upon compounds dissolved in the cell sap. The dying off of the cells naturally causes the loss of turgor; consequently, a softening of the fruit is the concomitant of its death.

A special experiment was made in regard to this mushy change[a] of the avocado fruit. Perfectly healthy fruits without any injury and with the stem still attached were selected and kept at 35° to 40° C. in a thermostat. After four days the skin commenced to turn brown, after two days more the fruit was soft and the skin had begun to shrink. Two days later the entire skin was deep brown and showed considerable and irregular shrinkage. On opening the fruit a brownish coloration, a peculiar, but not disagreeable odor, a sour reaction and taste, and some decrease of the slimy character of the flesh was noticed. Neither microbes nor mycelium were observable in the softened mass. Not even the most careful packing proposed will stop these changes, but cooling with ice will retard them.

[a] This condition of pears is sometimes termed doughy; in German it is called "teigigwerden."

REPORT OF THE HORTICULTURIST.

By M. J. Iorns.

INTRODUCTION.

As noted in former reports most of the work in the horticultural department will require several years to obtain definite results. Such being the case, the work for the past year has been, in a large measure, a continuation of the work of the preceding year.

As preliminary to contemplated research work a careful study of the horticultural conditions of the island was necessary in order that the new work planned might be of practical benefit to the fruit growers as well as of scientific value. With this object in view, a number of trips were made to the various fruit-growing sections, many of the plantations visited and, as far as possible, the conditions and needs discussed with the fruit growers. Everywhere the greatest cordiality and cooperation was met with. As a result, several lines of work have been outlined, both for the station and for cooperating planters. Among the chief of these to be noted are the questions of cover crops, treatment of pineapple plantings after the second year, stock resistance to "mal de goma," effect of stock on scion, pruning, and plant selection, and breeding for special purposes.

One of the greatest difficulties to overcome is that of obtaining trained help. This is especially true when real scientific investigation is undertaken. The development of the fruit-growing industries has been so rapid that there has been no time to develop trained help sufficient to meet the needs. It is to be desired that native young men with good common school education take up this work and thus further the development of the fruit industries.

Another of the great needs of the island is more adequate inspection laws. Thousands of plants are being imported annually and practically nothing is being done to prevent the introduction of such destructive, if not totally annihilating, pests as the bud rot of the cocoanut, the mango weevil, and various other equally injurious insects and maladies. Thorough inspection laws, with adequate provisions for enforcement, would prevent the serious damage to the fruit industries of the island by the introduction of these pests.

The following is a more detailed statement of the work being done or planned in the various specific lines.

VEGETABLES.

The conditions in Porto Rico are apparently so nearly ideal for vegetable growing that one at once asks why the island does not supply its own markets and ship quantities of produce to the States instead of annually importing thousands of dollars worth of onions, potatoes, beans, and various other vegetables. Work of the preceding years at the station demonstrates clearly that the majority of vegetables can be raised here in abundance, but that seed deteriorates rapidly, necessitating frequent fresh supplies from the States. Can we raise our own seed as well as acclimatize the northern types and maintain the standard of such types, and also develop our own forms to that standard? We are now investigating these questions, with much promise of an affirmative reply.

It would seem also as though vegetables could be had fresh from the garden every day in the year, as frost is not known, and a temperature of 95° F. is considered hot. Even a wet and dry division of the year can hardly be said to exist in a large part of the island, and along the south and southeast coast, where there is a severe dry season, there is water for irrigation. The local markets indicate, however, that there is still present some of the old belief that certain vegetables will not grow on the island or can be grown only at certain times. To emphasize the former work of the station, a number of experiments are being carried on to determine more definitely just what the special seasons are, if there are any. To obtain this necessary data for each class of vegetable several varieties of what former experiments showed to be the best for this section were chosen. Plantings are being made at regular intervals of about a month. The plants are subjected to different cultural methods, such as growing in shade, ridge bedding, etc. Notes are taken of growth, yield, quality, and general behavior, together with climatic conditions. This work has not been carried on long enough to obtain many definite results, but the conclusions of former experiments are clearly confirmed, as well as some new points brought out and new questions raised. The chief of these are: That with proper cultural methods such vegetables as radishes and lettuce do equally well at all times of the year, unless it be during the one or two months of greatest rainfall; that many others do have certain seasons in which they grow best and, generally, that these seasons are during the early winter and spring months; that the insect pests and diseases are, in a large measure, periodic; that tomatoes, melons, cucumbers, and some others can be grown here for a winter or spring market: that good seed of many classes can be home grown and, most important of all, that the better native varieties can be readily improved.

When more frequent steamship service between Porto Rico and the States is established, as it soon must be at the present rate of develop-

ment of the fruit industries, an important market-gardening business will undoubtedly be developed, adding to the wealth and prosperity of the island. Even at the present time there is a good opening for such work for local markets, and a great improvement is seen in both quality and variety of the garden produce in the markets of the larger Porto Rican cities.

As will be noted in the report of the entomologist, excellent success has been had in combating the garden pests and diseases, so that that bar to successful trucking may be largely overcome. Some of the more stubborn diseases, like wilts and mildews, can be overcome by breeding and selection. Excellent success has been had along this line in grafting choice eggplants on the wild "Berengena cimarrona." The grafts seem proof against disease, and the fruits borne by them were large and of excellent quality. The plants also bore several successive crops, and would seemingly have continued fruiting indefinitely like the stock parent had not a newly appearing insect destroyed the plants before the pest could be checked. Other grafts are now coming into fruiting and it is hoped more definite results will be obtained by the time for the next report. The same stock is being used on which to graft tomatoes with considerable success.

Much remains to be done in the acclimatizing of the better northern types of vegetables and, by cooperative experiments with planters in other sections, attempts are being made to determine the best locations for such important crops as potatoes and onions, which require certain conditions for the best results. Many northern types and types from regions similar to our own should be introduced and the choicest native strains improved.

ORCHARDS.

Much of the orchard work thus far has been a continuation of that of the preceding years. Many of the introduced varieties of fruit trees are coming into bearing, and these are being studied as to their adaptability to our conditions and their commercial value. Among those that give promise of sufficient merit to warrant further investigations are the Japanese persimmon, the Peen-to peaches, the cherimoyer, the loquats, and several of the imported guavas.

Systems of pruning are being introduced; various cover crops are being tried; the fertilizing experiments continued and new ones planned to show the effects of the different food elements under Porto Rican conditions, and a comparative test of clean cultivation against grass in the orchard is being made.

A number of various types of citrus fruits are coming into bearing this year, making it possible to determine their merits as to shipping qualities and general commercial value. (Pl. II, fig. 2.) Some are found to be not true to name and in other cases, though labeled differently, varieties are found to be the same.

NEW PLANTINGS.

In order to study in more detail cultural methods, diseases, and various other problems of fruit growing several new plantings have been made. The chief of these are a new citrus grove and a cacao grove, with rubber for shade. Other miscellaneous plantings of cocoanuts, shrub forms, and various imported types have also been made. The new citrus orchard is located on tile-drained bottom land. The soil is a strong clay silt with some pockets of slightly sandy nature. This orchard, together with the old one, give us marked contrast of soil and soil conditions and permits of a large range of investigations. Only standard varieties of each class of citrus fruits are planted in this new orchard, and these are so arranged that experiments requiring many years can be carried on.

The cacao and rubber planting consists of five of the chief varieties of cacao in alternate rows of Castilloa rubber from Central American seed and from the seed of our own trees. A few quick-growing "Madre de Cacao" and rain trees are interspersed to act as shade during the first few years. This planting is made for the purpose of studying the cacao diseases, the best cultural methods, the use of rubber as shade, and some other problems.

MISCELLANEOUS FRUITS.

Barbados Cherry (*Malpighia glabra*).—This fruit is proving of considerable merit for making jellies and has the advantage that it bears several crops each year. On the station grounds the trees thus far have borne one heavy and two light crops during the year.

Otaheite Gooseberry (*Phyllanthus disticha*).—This fruit also has been shown to produce a very excellent deep wine-colored jelly and, like the Barbados cherry, produces abundant crops several times during the year, thus making a very valuable household tree.

Anona (*Anona cherimolia*) has fruited during the year. While the fruits were small, they were all of most excellent quality. Other imported types are being planted, and it is hoped that this may become a common fruit in Porto Rico.

Rose Apple (*Eugenia jambos*).—A new use has been found for this fruit. When mixed with other fruits in making jelly or preserves it is found that it gives to the product a delicate rose flavor that is very agreeable. It would seem that this was well worthy of further trial.

Guavas.—The guava industry is one worthy of much attention and development. Since the pure-food laws prevent adulteration, pure jellies can be made profitably, as they will bring prices commensurate to their cost. Guava jelly is unquestionably one of the finest jellies on the market and the supply is almost nil compared to the demand. Hence the room for development is extremely large.

The guava is at home here, and there are many acres where it could be grown to advantage without interfering with other more profitable crops. It will grow in almost any situation, but responds readily to good treatment. The ideal conditions of soil, location, and culture are yet to be definitely determined. The introduced forms in the station orchard have thrived and this year bore excellent crops. Many hundred seeds have been gathered for sowing and for distribution. The mummy disease has not troubled the better imported types to an appreciable extent, and the native types have been kept nearly free by spraying (see report of entomologist, p. 38), so there is nothing to prevent the rapid development of this valuable industry.

Aguacate.—The avocados on the station grounds have not shown satisfactory growth. This is probably due to unsuitability of location and climatic conditions. They have also been subjected to a leaf disease, the cause of which has not been fully determined, which has defoliated them.

Cacao.—Our cacao has done quite well during the past year. The growth has been vigorous, with a relatively small percentage of disease. Thorough pruning is being tried, as well as soil and cultural experiments. In connection with the physiological chemist, methods of fermentation and preparation of beans for market, as well as of improving their quality will be investigated during the coming year. With the entomologist and pathologist, studies will be made of the diseases and pests of the cacao and means of controlling them. These are now a bar to the industry, but it is believed that they may be overcome and cacao planting placed on a successful basis.

COOPERATIVE WORK.

Considerable data have been gathered in the cooperative experiments, some of which promise valuable results. It has been found that in all the soils thus far tried a complete fertilizer gives a marked increase in growth over no fertilizer or one composed of one or two elements only. This increase has in two cases been over 25 per cent where single elements were used, and more than 50 per cent greater than upon the nonfertilized plat. In no case has there been less than from 10 per cent to 15 per cent gain in favor of a complete fertilizer.

Thus far no injurious effects of using chlorids or organic fertilizers have been observed in citrus groves. The "mal de goma" present in some groves has not been traced to the presence of organic matter, but in almost all cases seems to be due to too deep planting, bad drainage, or some allied cause. In our orchard fresh manure has been liberally spread about the trees with beneficial results.

During the coming year it is hoped that data may be gathered on the effects of the various food elements on the fruit itself, as several of the experimental plats will bear their first crops. The fruits will be

analyzed and compared for quality and shipping purposes. These experiments will be continued until definite results may be had on all of the questions raised.

COCOANUTS.

The past year has been very profitable for cocoanut growers; prices have been high and the crop fair. In favorable localities the crop has been very large. The high prices and the bearing records of the Porto Rican trees have given a great impetus to cocoanut growing and a number of large groves are being set out. There is also much general planting being done.

Efforts have been made to obtain some data regarding the number of fruits a tree will bear during the year. Though many countings have been made, the variation has been found to be so great that as yet it is impossible to give any accurate figures. Trees have been observed with as high as 225 nuts on at one time, and the bearing of from 125 to 150 nuts at one time has been found very common in the section where the cocoanuts are most at home. Most authors reporting on this subject give an average of 120 to 125 nuts for the whole year, but from data gathered here it would seem as though there is a higher average in the better cocoanut sections of Porto Rico.

Cultivation, fertilization, and seed selection are found to have an important influence on the rapidity of the grove's development as well as its productiveness. From data obtained it can be strongly recommended to those starting new groves that they look carefully to the physical condition of their soil, the selection of their seed, and the cultivation and fertilization of the trees. By thus doing they may gain from one to three years in the development of their groves.

Thus far none of the dreaded cocoanut diseases have been observed or reported. There are some minor diseases present in the groves, but they are almost entirely due to neglect of the trees and are not to be feared by the careful grower.

RUBBER.

Several of the Castilloa trees on the station grounds have flowered and fruited during the year. Many thousand seeds were gathered, most of which were distributed. It was determined that when the seeds were planted as soon as removed from their seed pods 97 to 98 per cent germinated. When left to dry out, the time of germination was lengthened and the percentage of those germinating decreased. Seeds allowed to dry for three weeks required as much as five weeks to germinate as opposed to five to eight days when fresh. The seedlings were found to stand transplanting very well. Some were transplanted twice, from seed boxes to pots and from the pots to

their place in the orchard, with but an exceedingly small percentage of loss—no more than is to be expected with any of the common tree types. How old the seedlings can be before they are stunted by transplanting is a question yet to be determined.

It is hoped that some tapping may be begun during the year, although the trees are less than 6 years old and too young for more than very light experimental work.

MANGOES.

The interest in mango growing is increasing. The mango tree makes in many ways the ideal permanent wind-break, so vitally essential to our citrus groves. Thousands of seeds are being planted and the demand for the better imported forms is rapidly increasing.

During the past year nearly 200 inarches have been made from the various imported forms and most of these are being planted on the station ground where wind-breaks are needed. Some have been distributed and others will be as fast as it is deemed advisable. Various methods of grafting, budding, and inarching are being given trial with more or less promising results. It is our desire to find if possible some rapid, simple way by which the seedlings may be grafted or budded in situ with more certainty of success than by any of the methods thus far used. Such a method will do away with much of the present necessary labor and danger of loss and will give an impetus to what should be a prominent industry on the island.

Shipping trials of mangoes were made during the season to further determine the best methods of packing, handling, etc., and the carrying qualities of the fruit. These experiments were successful as far as keeping qualities are concerned, and it seems only a matter of time until the mango will become a valuable factor in our export trade.

It was found that the best time to pick the fruit for shipping was when it began to show the faintest color of approaching maturity. Fruit picked at this stage arrived at its destination in excellent condition and developed a flavor and quality approaching that found in the fruit ripened on the tree.

Experiments were also made with the mango fruit for other purposes. At certain stages of maturity the fruit was found to make excellent jellies, butters, and sauces, and it is probable that it may be canned. More work is to be done along these lines in the coming year.

BANANAS.

The banana plantation is showing excellent growth and a number of the new varieties are now fruiting. These new types are being described and tested for their economic value. A number of forms secured from different sections, but bearing different names, are found-

to be the same, thus reducing the number of varieties in the trial grounds. Forms that have no merit are discarded.

The chief and vital objection to the growing of bananas for export has been the fact that the bunches were too small. In Porto Rico a bunch with six or eight full hands is considered large. Whether this characteristic of small bunches is due to the variety, soil or cultural methods is yet to be determined. The quality of the fruit is excellent and the number of bunches produced on a given acreage is fairly large, so that if the size of the bunch could be increased or more prolific varieties grown bananas could well be raised for export.

PINEAPPLES.

The pineapple industry has developed with exceeding rapidity and has become one of the chief industries of the island. The new acreage planted during the year was limited only by the available supply of slips. Not only were all the local supplies exhausted, but hundreds of thousands were imported from Cuba, Florida, and other pineapple-growing sections, and even then the demand was not met. This extensive planting may lead to great injury, as in many cases inferior slips were secured and the lack of inspection gave opportunity for the introduction of any and every form of disease and insect. Aside from the troubles arising from the planting of inferior slips no new disease or insect has been reported or observed. Growers should watch their plantings with great care and report any new trouble immediately, so that means may be taken to prevent the spread of any dangerous diseases.

The fertilization experiments that have been carried on for several years have been concluded and this information, together with much other data, is being prepared for publication. Observations made in the field have led to the undertaking of considerable other work with pineapples. It is necessary to more clearly determine the best methods for bedding, the treatment of the different soils, and proper soil conditions. Also considerable work is to be done along the line of plant selection and improvement. In several regions Red Spanish plants were observed that were practically spineless. Effort will be made to develop this characteristic. Several promising variations in type will be propagated and fixed, if possible.

During the past year pineapple shipments have been very satisfactory, both in carrying qualities of fruit and prices obtained. The new crate for the Cabezona pine, designed by the former horticulturist, Mr. Henricksen, has demonstrated its usefulness, and many thousand crates of this pine were put on the New York market in excellent condition. Should shipping become unprofitable because of low prices the planter has yet another resource, for new canning factories have been started at Mayaguez and San Juan, thus giving a larger home market.

Steps should be taken toward the adoption of uniform standards as to grading for quality, and more particularly for size. At present these standards are very indefinite, being almost entirely dependent upon the individual. Some size by weight, but most by the eye, and for the average man this is not accurate. Unless some means are taken to make the packages more uniform injury to the industry will result. These are proper questions for fruit associations to take up, and their committees should meet and formulate standards for use by all their members. The merits of a system of sizing by weight as practiced by some should be thoroughly discussed. If the crown of the pine did not vary so much weight would unquestionably be the ideal system to insure uniformity; but because of these extreme crown variations some modifications will be necessary.

The new varieties in the experimental beds on the station grounds have not done as they should, due to the extremely unfavorable conditions of most of the past year, and it is impossible to make any fair report of them at this time.

PLANT INTRODUCTION AND BREEDING.

As noted under their respective heads, new varieties of citrus fruits, pineapples, etc., have been introduced and distributed or planted in the experimental beds for trial or propagation. Some of the other special work done along these lines is as follows:

A large number of the standard varieties of grapes have been introduced and planted. They have made an exceptional growth during the year, and it has been found difficult to keep them within bounds. It has been observed that while in full growth heavy pruning can be done without seeming injury. Pruning when the vines were semi-dormant caused severe bleeding, which was checked only by cauterizing and then covering with wax. The best method is, of course, careful watching and pinching the buds before the growth fairly begins. By one or two heavy prunings at the proper time and pinching it is possible to keep the vines in good bearing condition.

The introduction of nut trees will be given considerable attention during the coming year. In many localities the conditions seem to warrant the belief that English walnuts, almonds, pecans, and other forms like Brazil nuts, litchi nuts, etc., can be raised here, and it is desired to take up the matter of their introduction, seeking the best localities and soil conditions for each form. Could these forms be used to reforest our hills and our waste places as well as be grown in groves it would add very materially to the wealth of the island.

Many new varieties of strawberries are being tested in the experimental plats. Some of these varieties have stood the adverse conditions of drought and excessive rains and are giving promise of producing excellent fruit. Others are yet too young to pass an opinion

upon. There has been enough work done in several places on the island to show that strawberries can be successfully grown. While the crop is not heavy at any one time as in the States, the bearing period lasts over several months, so that the total yield is very fair.

PLANT IMPROVEMENT.

In plant improvement special emphasis is being laid on the breeding for disease resistance in various varieties of plants. The tomato, eggplant, cucumber, and muskmelon are being given special attention. As stated previously, grafting tomato and eggplant on the wild eggplant has been very successful, and we are also trying by cross-breeding with the hardy native forms and by selection from the resulting hybrids to breed new, hardy types of high quality.

Most excellent success has been already obtained with muskmelons. A native strain of large size has been found with merit enough to warrant further work. By using fertilizers these have been grown to giant size while still retaining an excellent flavor. Another type locally known as the "melón de la China" has proven to be of exceptional merit for a breakfast or dessert melon, ranking well with the Rockyford in size and flavor and excelling it in appearance, being of a fine orange color when ripe. This melon is being tested for shipping, improvement of size, productivity, and flavor. Much is expected of this strain, both for home and foreign markets. A famous strain of Spanish muskmelon is also being tested.

Another line of work being pushed is onion growing. It is claimed by the dealers, and seemingly well substantiated, that the onions grown in the United States and even the Bermudas do not keep as well as the Spanish onions. Spanish onions have been planted and will be grown for seed. Efforts will also be made to obtain seed direct from Spain for trial here. There is no apparent reason why our large home demand can not be supplied and that large, important item of expenditure kept at home to add to the island's wealth. The success of the onion plats so far developed on the station grounds bear out the above conclusion.

Efforts are being made to adapt and grow the garbanzos, or chick peas, a Spanish vegetable that serves almost the same purpose as beans and is at present a large item of importation.

By selection an extra fine as well as extra early strain of cowpeas has been developed and now we are raising seed for trial at other points on the island.

Cowpeas promise much for Porto Rico, and any improvement will mean great benefit to the planters. The breeding crops thus far have matured in from sixty-three to sixty-eight days, and with favorable conditions it is probable that this time can be considerably reduced.

Practically all of the standard vegetables are under observation for adaptation and improvement and all the native strains that give any promise of merit are being tested.

FRUIT GROWERS' ASSOCIATIONS.

One of the encouraging signs in the growth of the fruit industries is the awakening of the planters to the value of cooperation. During the past year the two old associations have made a vigorous growth and one new association has been formed among the fruit growers around Manati. There is nothing that can build up an industry so rapidly and substantially as active, thorough cooperation, and fruit growing is especially susceptible to such efforts, as evidenced by the development of this industry in Oregon, California, Canada, and various other sections.

These associations are taking up the question of shipping rates and facilities and various other matters of importance in their lines of work. Unquestionably they can accomplish much good both for themselves and for the whole island. It is to be hoped that other associations will be formed in the various fruit-growing centers and then that all these local associations form a strong, vigorous federation. By such steps they can soon control the situation and bring about many needed shipping reforms.

REPORT OF THE ENTOMOLOGIST AND PLANT PATHOLOGIST.

By W. V. Tower.

No serious outbreaks have been reported during the last year, although there are a number of pests which are giving the planters a good deal of trouble. Several trips have been made through the orange and pineapple districts, and there seems to be a marked improvement in the groves. A number of beneficial parasites have been bred and their life histories are being worked out. These insects are to be bred and distributed during the coming season. Tobacco insects are causing the planters considerable trouble, and during the coming year cooperative work is to be carried on. Since March a great deal of time has been spent in studying the life histories of the insects affecting vegetables; also various methods for combating them.

ORANGE PESTS.

The "orange dog," a variegated caterpillar belonging to the genus Papilio, was found feeding on the orange during July. Some of these caterpillars were bred and pupated during August. The rest of the insects were fed on orange leaves sprayed with arsenate of lead, 4 pounds of stock to 50 gallons of water. This strength was effective. A second brood was observed October 18. The larvæ at this time were half-grown.

The orange leaf-weevil (*Diaprepes spengleri*) was found in limited numbers during the past season, but in the latter part of May great numbers were observed. At this time arsenate of lead, 3 pounds to 50 gallons of water, was sprayed on a number of trees, which were then tented, inclosing the weevils. In three days 75 per cent of the weevils under the tent were dead.

On one trip through the orange district there was found a very high percentage of scabby fruit. From the work carried on at the station it seems advisable for this trouble to spray just as the fruit forms, also again in ten to fourteen days. Trees treated with Bordeaux mixture showed a very low percentage of scabby fruit. It is advisable to have the scale well under control before spraying with Bordeaux mixture, as it kills the parasitic fungi which prey upon the purple scale.

As means of prevention: (1) It is not advisable to plant nurseries of rough lemon between budded rows of trees, as it is very suscepti-

ble to scab. (2) Do not plant nurseries on the windward side of groves, as the wind acts as an agent for distributing the spores of the fungus which produces scab. As scab and the orange weevil appear about the same time, it is recommended that a fungicide and insecticide be applied together. This can readily be done by dissolving 4 pounds of arsenate of lead in 50 gallons of Bordeaux mixture.

The red scale (*Chrysomphalus ficus*) is as pernicious as the purple scale, but there seems to be a definite time when the young come forth. The young settle down in about two days, forming their first covering. This first covering appears yellow, but it is transparent, the yellow of the insect shining through. The second covering is somewhat darker. These two stages are readily killed with kerosene emulsion, 1 part of stock to 6 parts of water. As the young are not all brought forth at the same time more than one spraying is necessary. For treatment spray when the crawling young first appear and repeat in three weeks. If the insect is very bad another spraying will be needed.

"Cuculios" or May beetles (*Lachnosterna* spp.) were reported in some of the groves this year at blossoming, while in some sections a number of planters observed the "cuculios" eating the young fruit, thus scarring it. If this is the case thorough spraying should be practiced before the fruit forms. It seems advisable, when there is a great amount of scab in the groves, to apply both a fungicide and insecticide—4 pounds of arsenate of lead to 50 gallons of Bordeaux mixture.

The brown or hemispherical scale (*Saissetia hemisphærica*) is not causing any serious trouble at present. It is readily held in check with 1 part of stock kerosene emulsion to 6 parts of water.

The purple scale (*Lepidosaphes beckii*) is causing a great deal of trouble in the citrus plantations. This insect has been under close observation for the past year at the station, and a number of planters have upon request sent specimens for study. From the observations made it was found that the young are frequently issuing. Experiments have been carried on to determine the value of the different strengths of sprays and at what stages the purple scale are killed by these insecticides. The adult females and eggs are very hard to kill, and a spray which would kill at these stages would cause many leaves to drop. Crawling young and young bearing their first covering are killed by much weaker solutions. Kerosene emulsion, 1 part of stock to 6 parts of water, kills larvæ with their first and second coverings. The complete history of this insect has not been worked out, and until this is completed it will be impossible to say just how many sprayings will be necessary to clean a grove.

FIG. 1.—TEMPORARY WIND-BREAK OF BANANAS.

FIG. 2.—PERMANENT WIND-BREAK OF MANGO TREES.

WIND-BREAKS.

Wind-breaks are now recognized as playing as important a part as sprays in checking the purple scale. During the past season many of the planters have been setting out groves with wind-breaks, and under such conditions parasitic fungi are developing.

Wind-breaks are divided into two classes—permanent and temporary. Permanent wind-breaks are generally planted on the outer borders of the groves, while temporary wind-breaks are planted between the rows of trees. There are several plants which grow very quickly and afford good wind protection, namely: Bananas, sugar cane, pigeon peas, and the China berry. Temporary wind-breaks (Pl. III, fig. 1) should not remain between the rows more than three years, and in the case of bananas a furrow should be plowed on each side, thus preventing the roots from sapping the soil around the orange trees.

For permanent wind-breaks at the present time the mango seems to be the best (Pl. III, fig. 2), but in setting out the young trees they should be headed as low as possible. Bamboo is also being planted, and if the cuttings are set out during the rainy season they start much quicker. These should be planted close together, so as to form a hedge.

When brush land is being cleared for planting it is advisable to leave a strip of uncut timber 20 feet wide every 300 to 400 feet. The results obtained from wind-breaks are very marked, certain groves which were wind swept and were not growing at all having been brought into excellent condition. In almost every grove on the island marked improvements by wind-breaks have been observed. In certain areas there may be found trees producing from one to two boxes of fruit, while trees not more than 50 to 70 feet away and of the same age as the former, but without wind protection, appear to be not more than a year old. On the latter the branches are blown to one side and covered with scale. Trees protected from the wind require less spraying and the fruit is free from scars.

The rust mite has been found in some of the groves during the past season, but very little damage has been noted. During the coming season various sulphur washes are to be tried in cooperation with the planters as measures against the rust mite.

KEROSENE EMULSION.

Kerosene emulsion made according to the usual formula has given excellent results at the station and also on many of the plantations: Take 2 gallons of kerosene, 1 gallon of water, ½ pound of whale-oil soap. First put the oil in a barrel. Then dissolve the soap in the

water by boiling and pour into the barrel. Mix the whole with a spray pump by pumping back into the barrel for ten minutes. A creamy mixture will be obtained which should hold up for from two to three weeks. For use follow directions given for the different insects.

TOBACCO INSECTS.

There are a number of insects which feed upon tobacco and which for convenience may be divided into two classes—those that damage the young plants in seed beds and those that damage the leaf in the field.

In making new seed beds it is a good practice to burn brush over the beds or to sterilize the soil by steam, thus killing all insects which may be present. Seed beds covered with a thin layer of powdered charcoal have been used at the station for preventing damping off and other similar diseases.

INSECTS WHICH INFEST SEED BEDS.

Young tobacco plants are killed by cutworms and "changas" and seriously damaged by flea-beetles and hornworms.

The "changas" and cutworms eat the plants when they are 2 or 3 inches high. The "changas" cut off the plants below the surface of the ground, while the cutworms cut the plants just above the soil. Paris green mash has been used at the station with excellent results. In using this poison it is advisable to make small cones, placing part of the mixture below the ground and part above. The mash under ground is for the "changas," while that above the surface is for the cutworms. This mixture is also very useful in vegetable seed beds, and in transplanting vegetables and tobacco a cone should be placed near each plant. The station recommends the following formula for Paris green mash: Twenty pounds of bran or corn meal, $\frac{1}{2}$ pound of Paris green, 1 gallon of molasses, and $1\frac{1}{2}$ gallons of water. Sprinkle the Paris green over the meal and thoroughly mix the two, then add the water and molasses, making a thick paste which can be molded into small cones.

Flea-beetles and hornworms do a great deal of damage to young plants. They may be controlled by spraying with 3 pounds of arsenate of lead to 50 gallons of water.

INSECTS FEEDING ON LEAF TOBACCO.

Flea-beetles and the hornworms are the most serious insects infesting tobacco. For these two insects 3 pounds of arsenate of lead to 50 gallons of water are recommended. No burning has been observed in using this insecticide.

Hornworms are causing much damage in the Cáguas and Cayey sections. The eggs and larvæ are gathered by women and boys. In July a parasite was found depositing its eggs in the egg of the hornworm. Notes were taken on the insect and as many as eight parasites have been secured from one egg of the hornworm. A great number of eggs of the hornworm were gathered and the life history of this insect was studied. From observations made it was found that the parasite takes about eleven days to develop. The adults mate very soon after issuing, and the females after depositing their eggs die in a short time. These parasites were determined by Dr. L. O. Howard as *Telenomus monilicornis.*

Nematodes have been found infesting seed beds. For their destruction soak the infested areas with a formalin solution, 1 tablespoonful of formalin to 1 gallon of water. This has given excellent results in beds where the plants are an inch high. A strong solution of mustard or tobacco water may also be used.

INSECTS AND DISEASES OF VEGETABLES.

During the spring and summer months cooperative work in spraying garden truck was carried on with the horticulturist. A number of interesting pests appeared, various sprays were tried, and those used on the insects were more successful than those used for the plant diseases. Bordeaux mixture and arsenate of lead were used together with excellent results. It was found that during the dry season all vegetables were comparatively free from disease, while those that were infested readily responded to treatment. This can also be said of the diseases found during the summer or wet season, except that the number of applications had to be increased, thus increasing the cost of production. *Plutella maculipennis* appeared the first part of the season and did considerable damage to cabbage, kale, mustard, and turnips. The larva is a very small green caterpillar three-eighths of an inch in length. It was found feeding on the under and upper surfaces of the cabbage leaves. The pupa case is generally made on the underside of the leaves, but occasionally it was found on the upper surface. Paris green and slaked lime, arsenate of lead, and kerosene emulsion were used, but as the cabbage leaves are very glossy the spray did not adhere. In May a parasite was found which deposits its eggs in the pupæ. A number of these insects were raised and set free. At the present date it is impossible to find any of the work of the caterpillars. Arsenate of lead was very effective as a spray for checking these insects on the mustard and turnip. Kerosene emulsion, 1 to 8, killed a large percentage of the larvæ, but it was not as effective as the parasites.

There have been two broods of the southern cabbage worm under observation, and a number of notes have been taken concerning its

life history. The females deposit their eggs in clusters on the under side of the leaves, the number of eggs ranging from 13 to 105, with an average of 45. The complete life history covers from 24 to 26 days. The egg clusters are readily seen on account of their yellow tint. These must not be mistaken for the eggs of the ladybug, which feeds on the larvæ of plant lice. The eggs of the cabbage worm are ridged, while those of the ladybug are smooth. Among the insecticides used arsenate of lead, 3 pounds to 50 gallons of water, was the most effective. Paris green 1 part and slaked lime 25 parts was also effective. This mixture should be dusted on the plants in the morning while the dew is on. Other food plants of the cabbage worm are radishes, turnips, kale, and mustard.

Tobacco hornworm eggs were found on tomatoes and pepper, but the larvæ were held in check by the egg parasite *Telenomus monilicornis*.

A white fly (*Aleyrodes* sp.) appeared in great numbers on the pepper and tomatoes, but no serious damage was noted. There appears to be a great number of parasites which should be encouraged. Two species of syrphid flies were bred, and part of their life history worked out. A parasitic fungus was also found on the white fly, and at the present time it is checking the ravages of this insect.

Plant lice (Aphididæ) were found on many of the vegetables, especially on the first two plantings. A number of parasites were found, two species of ladybugs were bred, and one species of syrphus fly, and a hymenopterous parasite was discovered laying its eggs in the pupæ. Tobacco water and kerosene emulsion were used during the first part of the season with excellent results, but at the present date parasites are playing a very important part holding the Aphididæ in check. Other food plants of Aphididæ are cabbage, turnips, mustard, melons, cucumbers, tomatoes, and squashes.

The striped cucumber beetle (*Diabrotica vittata*) was found feeding on the cucumber, squash, and melon, also on some of the native weeds. To combat them clean out all the weeds which act as food plants and then spray with arsenate of lead, 3 pounds to 50 gallons of water. It is advisable to spray with a mixture of Bordeaux mixture and arsenate of lead, as the Bordeaux mixture protects against the mildews and other diseases and the arsenate of lead against the insects.

SUGAR-CANE INSECTS.

Mealy bugs have been causing some trouble to the planters on the eastern end of the island. This pest seems to be spread by planting "seed" which has been taken from infested areas. A number of experiments were carried on at the station with kerosene emulsion, using it as a dip for infested canes. From figures obtained from these experiments it was found that with seed soaked for ten minutes in

kerosene emulsion, 1 part of stock to 6 parts of water (see p. 33), all insects were killed and 95 per cent of the canes germinated.

Specimens of sugar cane infested with the melanconium stage of *Tricosphæra sacchari* were collected from a number of plantations. An outbreak of this disease occurred on the south side of the island in a very limited area. This area is being treated.

For preventing this disease ratooning should not be practiced on infested areas. New plantings should be made with selected seeds which have been treated with Bordeaux mixture. After cutting the cane on all infested areas the infested stalks should be gathered and burned. Areas seriously infested should be burned as soon as the cane has been removed.

The sugar-cane weevil (*Sphenophorus* sp.) was found during December, January, and February in canes which were being cut for grinding. Borers were found in stalks, making large cavities between the nodes, and larvæ ranging from three-eighths inch to 1¼ inches long, pupæ, and adults were found in the same canals; eggs have not been observed.

The larva is a white, footless grub. The anterior portion of the head black, while the posterior portion is brownish red; mandibles black; anterior portion of first segment of body reddish brown. On segments 4 to 7 there is a swollen area or hump which assists the larva in locomotion. Anal segment bears 4 pairs of reddish-brown hairs. The adult is reddish with black markings. Head black; beak brownish red. Canes eaten by this borer become weakened and fall over, thus making a place for infection, and finally the whole stalk becomes infested with fungi. The treatment recommended is to collect and burn all infested canes at time of cutting.

A very small borer belonging to the genus Xyleborus was found infesting healthy canes. Upon examination all stages of this insect were found. The life of this insect is passed in sugar cane, males and females coming forth to mate. From the appearance of the canes the borers come forth from the nodes and in these canals fungi are found. The same treatment as for the weevil is advised.

The rice weevil (*Calandra oryza*) was found in very limited numbers. At present it is not causing any trouble.

PINEAPPLE INSECTS.

Pineapples during the past year have been comparatively free from diseases and insects. However, a few diseased plants have been reported in the San Juan section. A bacterial disease has been reported in Florida, and as many of the slips coming to the island are from Florida we may expect this disease.

Mealy bugs at present are causing a great deal of trouble. Young plants have been found infested, the trouble being traced to the parent plant. These infested slips should be dipped in kerosene

emulsion, 1 part of stock to 9 parts of water, for from five to ten minutes. Whole sacks or boxes of slips can be dipped at once, but these plants must not be left in the sacks or boxes for more than five to ten hours, as they will be liable to heat. When infested plants are set out in the field, ants distribute the young mealy bugs over the new growth, even to the base of the fruit. Insects were found in great numbers in the spaces between the calyx tubes, while on the outer edges of these cavities there appeared a secretion of gum which was probably caused by the mealy bug breaking down the cell structure. These areas were found on the green fruit, but upon microscopic examination no fungi were found. A number of these fruits were allowed to ripen, and the infested areas ripened first. A great number of immature mealy bugs were found in the closed calyx tubes, but it seems probable that the eggs were laid by the female before the calyx closed over.

Tobacco dust placed in the crown of the pineapple has given excellent results in checking the mealy bug. The rains and the dews collect in the crowns and dissolve the tobacco dust, thus making a strong extract, which slowly passes down over the base of the leaves and finally around the roots. Cotton-seed meal is used by many of the planters as a starting fertilizer for slips. In such cases it is recommended that the tobacco dust be mixed with the meal.

MISCELLANEOUS NOTES.

Icerya montserratensis was sent to the station for determination, having appeared on the orange. Kerosene emulsion, 1 part of stock to 6 parts of water, was recommended, and under this treatment the infested areas were cleaned.

Pulvinaria psidii was found on the orange and coffee.

Specimens of rufous scale (*Selenaspidus articulatus*) were sent to Mayaguez on the orange, and later it was found on the rough lemon. This scale appeared on the leaves, which were infested with purple scale, but the black fungus which was preying on the purple scale did not work on the rufous scale.

The wax scale (*Ceroplastes floridensis*) has been found during the past season on the rose and orange.

Mummy disease of guavas was reported in the last annual report as appearing on the imported Florida guavas. Last season the infection was about 40 per cent of the crop. The 1907 crop was sprayed with Bordeaux mixture a number of times and the mummied fruit was reduced to 10 per cent. These experiments are to be continued for a number of seasons to determine the proper time of spraying and the number of applications necessary to produce clean fruit.

The following mosquitoes were collected at Mayaguez, Porto Rico: *Aëdes mediovittata*, *Culex bisulcatus*, *Culex pipiens*, *Culex cubensis*, *Culex salinarius*, *Culex toweri*, and *Stegomia calopus*.

REPORT OF THE COFFEE EXPERT.

By J. W. Van Leenhoff.

The abundant blossoming of May, 1906, accompanied by excellent weather conditions, resulted in a large coffee crop. Storms lasting continuously from November 25 to December 14, 1906, and again from March 26 to March 28, 1907, did much damage to old and young trees, especially in less protected places. The young coffee was on different occasions thrown flat on the ground stripped of leaves, and had to be straightened and many trees sustained with forked sticks. Through the strong shaking by the wind, holes were formed in the soil around the trunks, which were carefully filled in with earth. The greater part of the trees recovered rapidly.

The results of these storms show the necessity of many more wind-breaks. As provisional protection plantains were planted between the rows, to be removed as soon as the shade had grown to a sufficient height. This is exactly what Porto Rican planters have done and, although their claim that young coffee wants heavy shade has not been proven, it seems that a statement that young coffee in Porto Rico requires many shade trees for wind-breaks would not be far from the truth.

IMPROVEMENT OF AN OLD COFFEE GROVE.

Experiments were continued and yields determined on different tracts of old coffee. These experiments are for the purpose of studying methods of bringing old coffee plantings up to a higher state of productivity. The crop from 10 acres in 1902 was 3,387 pounds. The plat was then divided into ten 1-acre plats, and on each a different method of treatment was followed. Altogether 1,106 trees were removed and others trimmed up. The yields since have been as follows:

Yields from a renovated coffee grove.

	Pounds.
1903	1,623
1904	1,184
1905	2,339
1906	4,349

The indications are that yields will increase for some years. Full details of the experiments will be made later in bulletin form.

Scarcity of labor, caused principally by the enormous demand in the tobacco industry, increased the price of picking 12½ per cent last year.

Cost of gathering and preparing 100 pounds of coffee for market.

Cost of picking	$1.56
Cost of field labor	1.45
Preparation for market	.75
Transportation from field	.20
Transportation from plantation to Ponce	.37½
Total	4.33½
Average price obtained per 100 pounds	10.88½

The following estimates are given of the cost of the new plantings of coffee:

Expenses per acre for 1907:		
Five weedings, at $1.33⅓		$6.67
Repairing damage after storm, estimated		3.00
One hoeing between rows		4.44
Expenses, third year		14.11
Expenses, first and second years		75.88
Total, three years		89.99
There was gathered the third year:		
80 pounds of coffee, worth $10.65 per 100 pounds	$8.52	
Less picking, preparing, and transporting	2.23	
		6.29
Net cost per acre to the end of third year		83.70

DISEASES AND INSECT PESTS.

All the diseases and insect pests mentioned in previous reports have continued to do more or less damage. The experiments in fertilizing to overcome the losses due to the leaf-miner (*Leucoptera coffeella*) seem to give good results, the field described in former report having not only completely recovered but showing very vigorous growth, with a very noticeable decrease of the brown spots on the leaves.

A new insect was observed in old coffee near Juana Diaz. A number of the trees were found to be attacked by a borer, which eats its way in a vertical direction through the heart of the trunks and branches. This pest is now under investigation.

EXPERIMENTS WITH NEW PLANTINGS.

The foreign coffees have been increased by the addition of some other of the best Javas, sent by the gardens at Buitenzorg, and by Blue Mountain coffee from Jamaica. During the coming year a number of introduced coffees grown on the experimental grounds will be submitted to experts for a determination of flavor.

THE FERMENTATION OF CACAO AND OF COFFEE.

By Oscar Loew, *Physiologist.*

THE FERMENTATION OF CACAO.

Although much has been written about the fermentation of cacao, there still exists a great difference of opinion in regard to the process, its purpose and necessity, and the kind of action involved in it.

Herbert Wright, in his exhaustive work on cacao [a], mentions yeast cells [b] as the most important organisms causing the fermentation, while other authors attribute the fermentation to unorganized ferments, others again to bacteria, and even the changes due to germination were supposed to play a rôle in it.

According to George Watt, in his Dictionary of the Economic Products of India [c]—

> The coolie dexterously strips all the beans off the center pulp. The pods are then thrown round the trees and act as manure, while the beans are removed to the fermenting cistern. It takes from five to nine days to properly ferment the cacao and it is then ready for working. It is trampled first, as in coffee, with the feet and then removed in baskets and carefully hand-washed. [d] * * * I have no doubt that before long some means less expensive will be found for washing. * * * The prices obtained for it will depend in the much greater measure on the careful attention of the curing than in the case of coffee.

Safford, writing on cacao in Guam, [e] says:

> Cacao beans are sometimes kept in jars and allowed to "sweat" or undergo a sort of fermentation which improves their flavor, but this custom is not universal. Many families, after having dried the beans in the sun, keep them until required for use, when they toast them as we do coffee, grind them and make them into chocolate. Chocolate made from the newly ground bean is especially rich and aromatic.

Hinchley Hart [f] writes:

> The prime object of sweating or fermentation appears to be to change the inside portion of the bean by absorbing into it products obtained from the fermenting pulp, and where this is not fully accomplished by any of the methods the bean is classed as unfermented, and the product is generally of lower value.

---

[a] Theobroma cacao or Cocoa. Colombo, 1907, p. 108.

[b] According to A. Preyer (Tropenpflanzer, 5 (1901), pp. 157–173), a special kind of yeast, which he named *Saccharomyces theobromæ*, effects the best fermentation in Ceylon.

[c] London, 1893, vol. 6, pt. 4, p. 44.

[d] Such methods are followed in India, but not in America.

[e] Useful Plants of Guam. U. S. Nat. Mus., Contrib. Nat. Herbarium, 9 (1905), p. 387.

[f] Cacao. Trinidad, 1900, 2. ed., p. 38.

The changes brought about by the fermentation have been minutely examined by J. B. Harrison, chemist in British Guiana. Some of the changes observed, as, for example, the decrease of protein in the seed and the increase of amido compounds, are only incidental and not of any importance, since they do not affect the color, which is simply due to the action of a proteolytic enzym in the seed.

The principal conclusions reached by Harrison [a] are that the process of "fermentation or sweating in cacao consists in an alcoholic fermentation of the sugars in the pulp of the fruit accompanied by a loss of some of the albuminoid and indeterminate nitrogenous constituents of the beans, * * * and some parts of the carbohydrates other than sugars undergo hydrolysis and either escape in the runnings from the boxes in the form of glucose or undergo in turn the alcoholic and acetic fermentations." Further he declares: "During this change some of the astringent matters, to which the somewhat acrid taste of the raw beans is due, are also hydrolyzed, and thus a marked improvement in flavor is gained." Finally he adds: "This work has necessarily only resulted in a partial and incomplete study of the results of the fermentation."

The so-called fermentation is carried out either by heaping the fresh seeds, after separating them from the shell, on the floor or in receptacles and covering them with banana leaves or with cloth. The floor or the receptacles slope so that the watery products can escape during the fermentation. A period of two to six days, according to circumstances, is usually allowed for fermentation. The height of the heaped seed measures 1 to 1.5 meters and over. In some countries the highest temperature allowed for fermentation is 45° C., in others 50° C. According to Hart [b] there is "danger in allowing [the temperature] to rise above 140° F. [60° C.], as the character of the product is sure to suffer." An apparatus has been recently devised by M. Schulte in which a constant temperature of 60° C. is maintained. In this case the yeast is fully excluded and bacteria with few exceptions also, and the necessary changes are brought on mainly by the heat, but this method has been considered too tedious and of little value to cacao planters, as is shown by Maurice Montet [c] in his criticism of the apparatus.

The rise of temperature amounts to about 5° C. in twenty-four hours, and after four days the fermenting beans show generally an elevation of 18° to 20° C. above the temperature of the surrounding atmosphere. The more or less rapid rise of temperature in the

[a] Proc. Agr. Soc. Trinidad, 2 (1896–97), p. 250; Hart, Cacao. Trinidad, 1900, 2. ed., pp. 106, 107.

[b] Cacao. Trinidad, 1900, 2. ed., p. 42.

[c] Jour. Agr. Trop., 5 (1905), No. 52, p. 297.

fermenting pile depends, of course, upon the height of the pile and upon the temperature of the surrounding air.

The cacao fruit resembles a cucumber in shape, but the form is subject to certain variations. The shell is of violet, red, or yellow color, sometimes even nearly white, 15 to 25 centimeters long and 6 to 10 centimeters thick. The shape of the seed is more or less round, often laterally compressed or flattened, when it resembles the bean of Phaseolus; its length varies from 2 to 2.5 centimeters, the diameter from 0.8 to 1.8 centimeters. Between the fleshy and corrugate cotyledons, showing convolutions on the surface, lies the bitter, purple

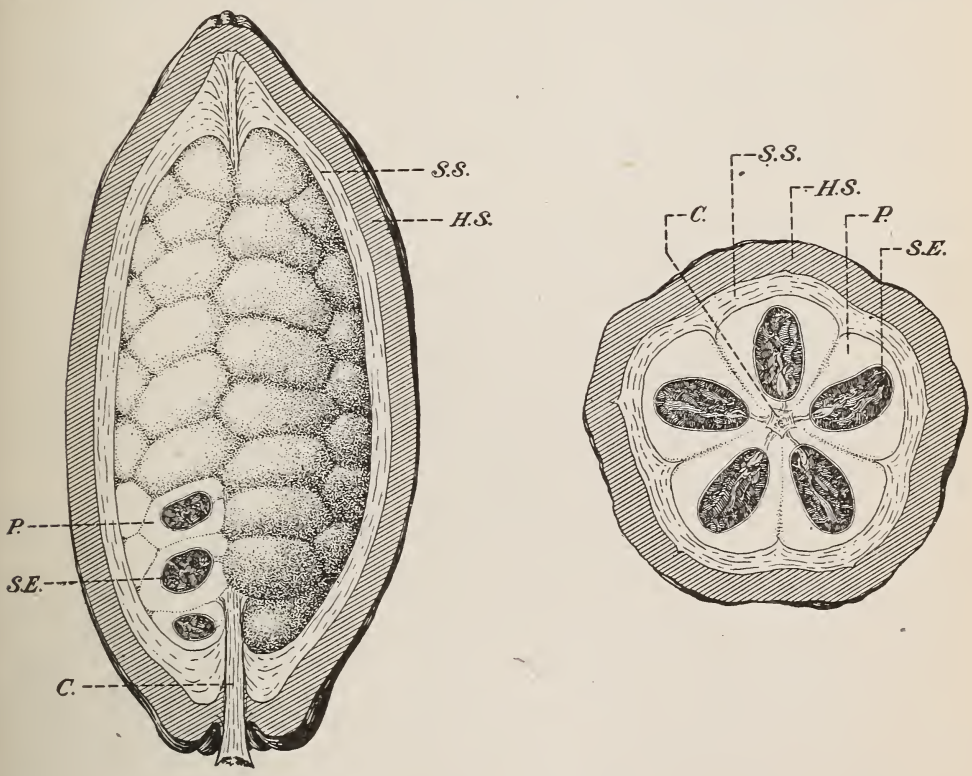

FIG. 1.—Structure of cacao fruit: *H. S.*, Hard outer shell of fruit; *S. S.*, soft inner layer of fruit shell; *P.*, pulp of seed or slime tissue; *S. E.*, seed with testa or envelop; *C.*, core or placenta.

embryo with its white chalaza. The cotyledons of one variety are white in color. There may exist in one fruit as many as 50 seeds. The loose parenchymatous slimy tissue (pulp) surrounding the testa of the seed appears to be of similar nature to the tissue forming the soft inner layer of the hard fruit shell. The structure of the entire fruit is somewhat complicated, and nature has evidently taken much pains to protect the embryo by four different envelopes. Figure 1 will suffice to explain the structure.

The chief purposes of the fermentation process are:

(1) Removal or contraction of the pulp surrounding the seeds.

(2) Loosening of the connection between the seed and its testa.

(3) Development of color and improvement of taste.

Some authors hold that the heat of the fermentation is required to harden the interior of the bean, and also pass it to a second fermentation; further, that another change consists in the hardening or toughening of the testa of the bean, whereby brittleness is avoided during drying, and thus the seeds are better protected against the entrance of mold fungi.[a] Various authors also ascribe to the fermentation a great influence upon the development of the aroma.

As regards the first of the above-named purposes, namely, the removal of the slime layer attached to the seed coat, a somewhat similar process occurs in the fermentation of coffee. (See p. 52.) The first step is the development of numerous yeast cells, which find ample nutrients in the sweet juice oozing from the pulp. The yeasts are chiefly *Saccharomyces ellipsoideus* and a certain amount of *S. apiculatus*, which develop rapidly. These organisms occur on fruits, as well as in the dust of the air and on the surface of the soil, together with numerous bacteria. The alcohol formed in the fermentation of the sugar by these yeasts destroys the superficial strata of the pulp or slime tissue, and as its juice passes freely to the outside, nourishment is given to innumerable bacteria, among them the widely distributed acetic bacillus. The respiration of these organisms and the fermentative activity generate heat and gradually a considerable elevation of temperature is reached.

The juice on the surface now assumes a strong acid reaction, due to the oxidation of alcohol to acetic acid, and this suffices to destroy the remaining cells of the slime layer, causing thereby a considerable shrinkage of it and also a further discharge of juice, as the cytoplasm of the dying cells becomes permeable to the interior juice. Thus a considerable amount of liquid gathers at the bottom of the receptacles and, since this liquor has an agreeable sour smell and taste, it is used in some factories as vinegar. By the bacterial action the attached pulp is further loosened from the testa to some extent and can be washed away, as is done in Ceylon. In many parts of Central America, however, the shrunken pulp is dried with the beans, which are shipped in this condition to other countries.

The fermented and well-washed cacao beans show a uniform yellowish or brownish coloration of their testa. The testa of unwashed fermented beans do not show a uniform coloration on account of the adhering films of fermented and shrunken pulp, which has turned from the original colorless condition to a violet brown color, and which is reduced from the original thickness of 0.1 to 0.2 centimeter to a mere film. An advantage of removing the remaining films by washing consists doubtless in the greater rapidity of drying, whereby

[a] Hart, Cacao, Trinidad. 1900, 2. ed., pp. 35, 49.

the danger of attack by mold fungi is diminished. E. Lange[a] holds that the extra trouble is not compensated by the additional price obtained for washed cacao. Nevertheless, the washing of the cacao has been recently introduced in Trinidad.

When pulped cacao is not fermented, but simply dried in the sun, the slimy layer around the testa shrinks considerably, but not to such insignificant thin films as after fermentation. When the entire juice of the slimy layer is simply dried up instead of being removed, a hygroscopic condition of the product results, which in moist weather becomes sticky and might support fungus growth. Hence, fermentation is preferable to a simple drying process, and after washing yields a much cleaner product.

In the fermentation of coffee the slimy layer to be removed from the testa (parchment envelope) is much thinner than that of the cacao seed. Hence, the fermentation of coffee is of much shorter duration than that of cacao.

In regard to the second purpose above mentioned, namely, loosening the connection between the seed and its testa, it must be mentioned that by the death of the seed, caused by the elevation of temperature of the fermentation to 40° to 45° C., some contraction takes place and the seed recedes somewhat from its walls. Later on, in the manufacture of cacao from the fermented and dried beans, they are roasted and some further contraction of the seed is caused. The testa having lost its hygroscopic water by the heat, now can be easily separated, especially while still warm and brittle.

An important change also due to the fermentation process is the production of a fine brown color. The effect of the fermentation in this direction is, however, not a direct, as supposed by many, but an indirect one, and may be secured by simply drying the bean. Sun-dried beans are uniformly deep brown. When the fresh seed is cut, the surface thus opened will turn from the original violet to a deep brown color within a short time, while boiled seed thus treated will not show any change of color, even after many hours' exposure to the air. This is in full analogy with similar phenomena observed very frequently with plants, and is due to the presence of oxidases or oxidizing enzyms. When cells are killed by being cut open or in any other way that will not injure the oxidases, these will, upon the death of the protoplasm in which they were stored up, be liberated and commence at once their activity, easily recognized by the early appearance of a brown, black, or red color. These colors are generally due to the oxidation of various kinds of tannins originally present in the juice or cell sap.[b] If, however, the death of the proto-

[a] Agr. Record [Trinidad], 4 (1891), pp. 105–107.

[b] Such a case is observed in the curing of tobacco, whereby a fine brown color is produced.

plasm is produced by strong acids or boiling temperature,[a] the oxidases will also be killed and no color change will be noticed, as the tannins and other readily oxidizable matters in the juices can not easily take up the atmospheric oxygen without the assistance of oxidases.

A further control experiment was made in which the pulped cacao (seed with testa and attached slime layer) was boiled for about twenty minutes with dilute sulphuric acid of 2 per cent. The slimy tissue contracted and together with the swollen testa was easily separated from the seed. These seeds showed a pure red coloration on the outside, while the interior was violet, and no trace of brown color appeared even after many hours exposure to the air, since the oxidizing enzym (oxidase) had been killed, together with the living matter (the protoplasm of cells).

The seeds commence to die when the entire fruit is kept for several days at 40° to 45° C., and the browning can be observed progressing from the surface of the seed toward the interior. By becoming overripe, the soft interior strata of the fruit shell, as well as the slime tissue around the seeds, contract more or less and a hollow space is formed between the fruit shell and the seeds with their adhering slime tissue. Air diffuses into this space, and the reason for the brown color produced by oxidation within the fruit becomes apparent. During the fermentation process the browning does not often go farther than this, and the interior of the seed often continues to show the original violet coloration. It is then that the subsequent drying process, which admits air abundantly by diffusion through the testa, completely finishes the browning process. Some further darkening can take place during the roasting process when powdered cacao and chocolate are made from the fermented beans.

The color change of the cacao seed is no doubt similar to the color change in the preparation of black tea, for which it has been positively proved[b] that an oxidizing enzym acting on a specific tannin is the real cause of the blackening of the leaves. When the oxidizing enzym of the tea leaves is killed by steam, the leaves retain their green color and never turn black (green tea).

Tea leaves contain 7 per cent tannin and over, and the production of a black color from this tannin commences as soon as the leaves die, which takes place when they are kept in heaps after picking and are deprived of sunlight (death by starvation). Indeed, black tea contains less tannin than green tea. In order to increase the black coloration the leaves are rolled, which brings their juice to the surface, and the access of air accelerates the blackening process.

---

[a] The killing temperature for oxidases is 20° to 30° C. higher than that for protoplasm or living matter.

[b] K. Aso, Bul. Col. Agr. Tokyo, Imp. Univ., 4 (1900–1902), p. 255.

A case in which tannin is changed by partial oxidation for the sake of removing the astringent taste is observed in the curing of the fruit of certain varieties of persimmon (kaki) in Japan. By the curing process, which consists in keeping the fruits in vapor of alcohol or in subjecting them to slow desiccation in the sun, the tannin is changed, in contact with an oxidizing enzym and oxygen, to a brown, tasteless substance.[a] The fruit thus acquires an agreeable taste.

Since a moderate brown color is also produced in white "nibs," free of cacao red, it follows that the brown coloration is not due exclusively to a change of cacao red. If the production of the color is due to an incomplete oxidation of the tannin, then there will be less tannin found in the cured cacao than in the fresh cacao. This agrees, indeed, with some analytical determinations of J. B. Harrison, published by Hart.[b] The fat content is assumed not to change during the curing process, and this is in all probability the case. The data compiled under this condition are as follows for Calabacillo cacao:

Analyses of Calabacillo cacao.

Constituents.	Fresh.	Cured.	Constituents.	Fresh.	Cured.
	Per ct.	*Per ct.*		*Per ct.*	*Per ct.*
Fat	29.25	29.25	Glucose	0.99	0.60
Tannin	5.00	3.61	Hemicelluloses	5.11	3.74
Cacao red	2.95	1.39	Woody fiber	3.03	2.78
Theobromin	1.35	1.00	Protein	6.69	4.42
Caffein	.11	.03	Amido compounds	.53	2.06
Starch	3.76	3.22			

A part of the changes brought about by curing is probably due to the action of the living cells in the seed, before they are killed by the rising temperature. This would account for the decrease of starch, glucose, and hemicelluloses, which may be consumed by the respiration process, but the other changes are due to several enzyms. A proteolytic enzym brings on the decrease of protein and the corresponding increase of amido-compounds, while oxidizing enzyms, generally liberated from the protoplasm upon its death, cause the decrease of tannin and cacao red and their change to other compounds. The most conspicuous changes are, therefore, only possible after the death of the protoplasm, which is a desirable factor. Hence, it is a mistaken idea of Zipperer that the changes are due to a germination process of the seeds. He has even attributed the rise of temperature of the fermenting pulp cacao to this process, considering it analogous to the behavior of barley on the malting floor. This error can only be explained by the fact that he has never witnessed the fermentations

[a] S. Sawamura, Ibid., 5 (1902–3), p. 237.

[b] Cacao. Trinidad, 1900, 2. ed., p. 100.

of cacao or coffee; for germination changes are not in the least apparent.

Another result is the change of flavor. In the fresh state the seeds have a raw, bitter, and astringent flavor, while after fermentation and drying the bitter and disagreeable taste has entirely disappeared. This change is doubtless due in a certain measure to the decrease of tannin; that is, to its change by oxidation to a brown substance, as in the case of the persimmon fruits, mentioned above.[a] The flavor of the fermented beans is still far different from that of the prepared cacao product, which is produced by roasting the fermenting beans; hence a part of the taste must be due to changes caused by the heat of the roasting process.

The presence of oxidizing enzyms in the seeds of cacao can be proved by the usual reaction. Upon moistening a freshly cut section of cacao seed with tincture of guaiacum resin, just after taking the seed from the ripe fruit, a blue color is rapidly produced, first and most intensely in the chalaza of the embryo and gradually spreading over the entire seed tissue; also, the placenta shows soon an intense blue color. When a cross section through the whole fruit is moistened with guaiacum tincture, the chalaza of the embryo and the interior soft stratum of the fruit shell become rapidly and intensely blue, then follow in order the coloration of the convolutions of the cotyledons of the seed and the tissue of the hard outer shell. Finally the whole surface of the section of the seed and the exposed tissue of the testa become blue; but the slime tissue or pulp around the testa remains perfectly colorless, presenting a most striking contrast.

If the tissue of the seed is crushed with some water in a mortar, the filtered liquid will show no blue coloration on addition of guaiacum tincture and shaking with air, while the unfiltered liquid will become blue very soon. This shows an exceptional case, namely, that the oxidase (laccase) is present in an insoluble state and perhaps held in combination with an insoluble protein.[b] Upon standing the blue color, obtained with the unfiltered liquid, will gradually disappear, except on the surface, but on adding a few more drops of the reagent and shaking, the intense blue color reappears. This phenomenon is due to the presence of a reducing compound in the juice.

In testing for a second oxidizing enzym, the peroxidase, the tissue of the seed, crushed with a little water, was heated for five minutes to 75° C. and one portion of this liquid was filtered; the other not. The test with guaiacum tincture yielded no blue reaction in either liquid, proving that the oxidase was killed, while on addition of a little peroxid of hydrogen the unfiltered juice gave an intense blue reaction

[a] The opinion of Harrison mentioned above that the decrease of the astringent taste is due to a hydrolysis is erroneous and would be without analogy.

[b] This recalls the existence of a soluble and insoluble form of catalase.

and the filtered juice showed only a trace. This difference proves that the peroxidase, like the oxidase, was present, but retained as an insoluble compound—an exceptional case.

Reactions with guaiacol were also tried. This substance produced no coloration when applied by itself, but in conjunction with hydrogen peroxid a red color turning to brown was soon produced in both the hard as well as the soft layer of the fruit shell. Later, in the testa and the seed in general, as well as in the slime tissue covering the testa, only a weak, reddish coloration was produced. This peroxidase reaction agrees also with that just mentioned, in so far as the slime tissue gave only an exceptionally weak reaction compared with all other parts of the fruit. The slime tissue of the coffee fruit is also poorer in oxidase and peroxidase than the other tissues.

The further generation of the characteristic aroma of cacao is of great importance. Is this process due to the action of an oxidizing enzym or to that of a hydrolizing enzym, and does the fermentation influence the generation of aroma only indirectly by the development of heat or directly by furnishing some compound? Or, is the roasting of the fermented cacao beans alone responsible for the aroma? The investigations thus far made do not solve this problem satisfactorily. It may be mentioned, however, that Hart [a] agrees with Chittenden,[b] who declared that after a certain stage of the fermentation "the cotyledons are found separated and the vinous liquor of the pulp, which passes through the membranous covering, occupies this space as well as the cavities between the convolutions. * * * This it is which has so marked a physiological influence and affects its flavor, the bean being, as may be said, 'stewed in its own juice.'"

According to the laws of osmosis some acetic acid and some alcohol from the fermenting liquor will doubtless enter through the testa and come in contact with the cotyledons, which thereby may be killed, if the temperature of the fermenting mass has not already accomplished this. The reaction of the cotyledons after drying the fermented beans is acid, but whether this is wholly due to the entering acetic acid may be doubtful, since the reaction is weakly acid in the fresh state. A stronger acid reaction is shown by the slime tissue.

The expression "stewed in its own juice" used by Chittenden can hardly be admitted, since the juice of the pulp, after being entirely decomposed by yeast and bacteria, is certainly not the "own juice" of the cotyledons. Still, that author attributes to it the generation of the flavor.

---

[a] Cacao. Trinidad, 1900, 2. ed., p. 38.

[b] Agr. Record [Trinidad], 2 (1890), p. 110.

The opinion of J. B. Harrison (see p. 42) that the decrease of tannin during the fermentation process stands in relation to the development of aroma (see p. 48) is certainly far from the mark, as tannin can not produce ethereal oils by any oxidation or fermenting process. Only color and taste stand in this relation to the tannin content.

Several experiments were made by the writer with an aqueous solution of 1 to 4 per cent acetic acid containing from 3 to 5 per cent of alcohol in order to imitate the composition of the fermenting pulp juice. After twenty to thirty hours digestion of pulped cacao at 40° to 44° C. it was observed that the pulp had died and shrunk to skinny masses, partly separating in small pieces, but mostly still firmly adhering to the testa. It appears that for bringing about an easy separation of the dead pulp from the testa a bacterial enzym is necessary, as in the case of coffee fermentation. It was further observed that the amount of acetic acid, which entered by osmosis through the testa to the cotyledons, was not sufficient to kill the oxidizing enzym, since the freshly cut surface of these seeds rapidly turned brown on exposure to the air. On the other hand, it was observed that when the freshly cut surface of the seeds so treated was moistened with 4 per cent acetic acid no further change by oxidation took place. In this case the oxidizing enzym was killed.

It is stated by Hart [a] that "of late years there has been a large amount of inquiry for cacao which is but slightly fermented or not fermented at all." This renders it very probable that the decomposed juice of the slime tissue is not required for the generation of the aroma, as was supposed. Indeed, the true aroma of cacao is faint before roasting the fermented beans. The case is, therefore, similar to that of coffee, and is different from that of tea. With tea the aroma is the result of the action of a hydrolizing enzym, yielding the volatile tea oil, as was shown by Katayama.

That the aroma of the cacao is chiefly produced during the gentle roasting process is the opinion of manufacturers of chocolate from the fermented beans. The fermentation seems, indeed, to have nothing at all to do with the production of aroma. Seeds simply dried in the sun and then gently roasted may yield an especially rich and aromatic chocolate, as Safford [b] has also indicated. Hart says:

> No adulteration * * * is equal to the flavor of the virgin cacao, provided the essential oil has not been destroyed during the process of roasting, during which process it appears to be developed.[c]

The question now arises, Which compound yields the aroma in the cautious roasting of the fermented cacao beans? It is certainly not

---

[a] Cacao. Trinidad, 1900, 2. ed., p. 33.

[b] Compare the quotation in the introductory remarks to this article.

[c] Cacao. Trinidad, 1900, 2. ed., p. 111. These words contradict his other opinion, however, quoted above in regard to the influence of fermentation on aroma.

a glucosid, for neither the testa nor the cotyledons of the beans develop anything like a cacao flavor upon being boiled for some time with dilute sulphuric acid (3 to 6 per cent). The same negative result was obtained by boiling those materials with moderately concentrated solution of caustic potash. It seems probable that it is a certain concomitant of the fat which causes the production of the flavor, after being moderately oxidized during the drying of the beans. Only seeds in which the oxidizing enzyms have produced changes can yield the true aroma by roasting, not the fresh beans.[a]

In the manufacture of the cacao powder of commerce the fat of the cacao is removed more or less, since a suitable powder can not otherwise be obtained, but in the direct manufacture of chocolate this removal of the cacao fat can not be justified. It is claimed that cacao fat or cacao butter is difficult of digestion, but in reality cacao butter is as easily digestible as cow's butter. Besides, the removal of fat also diminishes the aroma of the chocolate. In the manufacture of chocolate in Porto Rico, fermented cacao seeds are placed in a small baker's oven for about one hour, until the testa have become very brittle and can be easily removed. This roasting temperature is kept considerably lower than that required for baking bread. The cacao butter is not removed in Porto Rico, and therefore the chocolate manufactured there has an exquisitely fine aroma.

SUMMARY.

The fermentation process itself is due in the first place to yeast cells which multiply rapidly in the saccharine juice oozing from the pulped cacao and produce alcohol and carbon dioxid. In the second place bacteria participate, which develop rapidly after a certain time, and change the alcohol formed by the yeast by oxidation, either wholly or partly, into acetic acid. These processes cause a rise of temperature and the death of the cells of seed and slime tissue, whereupon the juice of the slime tissue, more or less altered, collects at the bottom of the receptacles, together with the acetic acid produced.

The chief object of the fermentation is to shrink the slime tissue or pulp attached to the testa of the seed, allowing the remnants either to be washed away, as is done in Ceylon, or dried upon the seed, forming an irregular brown film upon the testa. The advantage of thus changing the voluminous slime tissue lies in the increased facility of quickly drying the seed. In this regard there exists a close analogy to the fermentation of coffee. The loosening of the adhe-

[a] Fresh beans were crushed, washed with alcohol, and extracted with ether. Neither the extracted fat nor the seed powder developed on moderate heating any flavor resembling that of cacao; only the alcoholic extract yielded thus a very faint flavor of cacao. On evaporation of the alcoholic extract another aromatic odor is noticed.

sion between seed and its envelope and the hardening of this envelope (testa) are claimed as further effects of fermentation.

The fermentation has also an indirect influence on changes going on within the seed, inasmuch as by the temperature produced (40° to 50° C.) the cells of the seeds are killed, thus liberating the oxidizing enzyms, which cause the formation of the brown color, by oxidation of the tannin of the seed. This brown coloration is increased during the drying process and finally by the roasting.

The taste of the raw cacao bean is not only altered by the partial oxidation of tannin during the fermentation or sun drying of the seed, but also by products of roasting.

The action of oxidizing enzyms, as well as the final roasting process, play a part in the development of the aroma.

THE FERMENTATION OF COFFEE.

The so-called fermentation of coffee has thus far not been investigated, and has been defined sometimes as an "alcoholic fermenta-

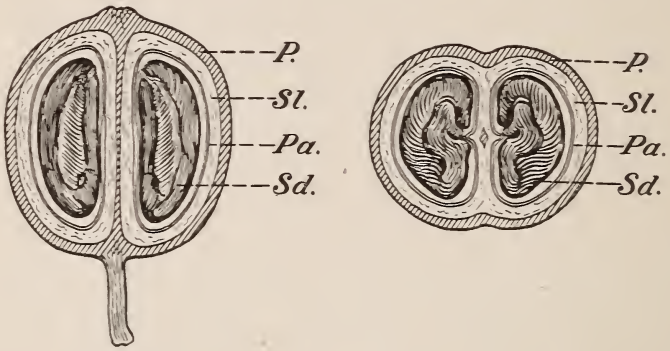

FIG. 2.—Structure of coffee fruit: *P*, pulp; *Sl*, slimy layer; *Pa*, parchment envelop; *Sd*, seed with silver skin.

tion necessary to remove the saccharine matter."[a] Such saccharine matter, however, should be easily removable by simply washing with water. Upon close examination the writer concluded that the aim of the "fermentation" is the removal of a slimy stratum firmly adhering to the parchment envelope of the seeds. The removal of this is necessary, because the drying of the seed envelope would otherwise be very much retarded, and because a bad flavor may finally be imparted to the seeds by the partial decay of the slimy stratum during the drying process. The process will be explained by examining the anatomical structure of the fruit. (Fig. 2.)

Just below the skin of the fruit and extending between the enveloped seeds is a fibrous tissue containing a sweet juice. This pulp, together with the skin, is easily separated by mechanical means from

[a] Cf. Watt, Dictionary of the Economic Products of India, Calcutta, 1889, vol. 2, p. 476.

the seeds, which are enveloped in a hard parchment. Adhering to this parchment is a stratum of very slimy cells, the slime layer.

The preparation of coffee for market requires the following manipulations:

(1) Pulping to secure removal of the skin with the adhering tissue.

(2) Fermentation to separate the slimy layer from the parchment envelope.

(3) Washing away the loosened slime.

(4) Drying the envelope around the seeds, preparing for the necessary brittleness for the next operation.

(5) Hulling or milling, consisting in the removal of the parchment envelope, with subsequent subjection to a fan to blow away particles of parchment envelope and silver skin.

The entire fruit is often called "cherry" from the similarity of form and color. The expression "pulped coffee" signifies seeds in the parchment envelope with slimy layer. "Coffee in parchment" means the product after pulping, fermenting, and drying. The "bean" means the seeds deprived of parchment and silver skin.

Fruits of red or yellow color should be picked for pulping, as only such furnish seeds of the desired bluish-green color. Green unripened fruit containing a hard pulp and little or no sugar should be excluded, but such fruit can not be entirely avoided, since some unripened seeds will drop off in gathering the ripened ones.

The fruits are well moistened with water when passing through the pulper, which easily separates the skin and fibrous layer. Attached to the pulper is a conical sieve ("separateur") placed in a horizontal position, which retains the fruits which have accidentally escaped pulping, and they are carried back to the pulper.[a]

In order to understand the fermentation process it must be remembered that on the surface of all sweet fruits are a great many yeast cells and bacteria. When by the pulping the sweet juice is forced out and spread all over the separated skin, and over the pulped coffee, it is not surprising that these organisms develop rapidly. The sweet

[a] It has been proposed to dry the pulp and bring it into commerce as a cheap substitute for coffee. When pressed well to remove the caffein and mixed then with molasses, it might serve as a food for hogs. Greshoff holds that the best application is as a manure and gives the following composition in the air-dry state:

	Per cent.
Caffein	1.1
Carbohydrates	23.3
Albumin	7.6
Cellulose	16.1
Water	14.9
Fat	3.3
Ash	6.9

juice not only contains sugar, but also some nitrogenous and mineral matters required for the development of organisms.

An examination of the skin with a high magnifying power several hours after pulping shows numerous cells of Saccharomyces, which in form resemble chiefly *Saccharomyces ellipsoideus* and sometimes also *S. apiculatus.*

Numerous bacteria are also present. Alcoholic fermentation can soon be detected by the vinous odor, and the fact that the fermentation produces heat explains why the temperature of such a heap of pulp rises considerably after a time. A heap of nearly 30 centimeters in height showed after sixteen hours a temperature of 41° C. at an air temperature of 26° C. Later, acetic acid is formed and the red color of the skin is changed to a brownish one.

When the pulped coffee, on the other hand, is examined, few yeast cells and bacteria are noticed on the slimy stratum after one hour, while after sixteen hours an immense increase has taken place and not only is considerable alcohol formed by the yeast cells, but also acetic acid by certain bacteria. Mycoderma and the mycelium of fungi are occasionally seen. Litmus is reddened intensely and the odor of acetic acid is readily discernible. At the same time another volatile product is formed in small quantity, which modifies somewhat the acid odor.

The alcoholic fermentation of the sugar adhering to the slimy stratum, as well as the further oxidation of the alcohol to acetic acid, and finally the respiration process carried on with considerable intensity by all these organisms, cause a rise of temperature, depending upon the depth of the stratum and the temperature of the surrounding air. The heaps of pulped coffee are generally 1 to 2 feet high. In such heaps the temperature was found after fifteen to sixteen hours to range from 34° to 42° C. at an air temperature of 25° to 29° C.

The alcoholic and acetic fermentations proceeding in the heaps of pulped coffee are, however, not the most essential phenomena; the most important point is that the slimy stratum is separated from the parchment envelope. It is by no means dissolved, but merely loses its firm adhesion and is left loosely spread upon the parchment coffee so that it can easily be washed away by a current of water and the parchment coffee dried.

Neither the acetic acid nor the enzym already present in the slime causes the separation of the slime layer, as tests have shown.

Freshly pulped coffee was kept in dilute acetic acid (about 1 per cent) at 35° to 40° C. and another portion in some water containing a few drops of ether to prevent bacterial growth. In both cases the slimy layer was found still firmly attached to the parchment after twenty-four hours. This leaves no other inference but that a peculiar enzym dissolving the adhesive substance (a carbohydrate?) between

the parchment and the slimy stratum was furnished by the bacterial growth, or, what is less probable, by the yeast cells.

The "fermentation" should not take longer in Porto Rico than fifteen to twenty hours, while in some sections of Central America, as Guatemala, it must be carried on for two days.

Undue prolongation of the fermentation must be avoided, as otherwise a brown coloration of the parchment and of the seeds is produced; the seeds further acquire a disagreeable odor—two circumstances which render the product unfit for the market.

After the fermentation and washing the parchment coffee is readily dried, either on cement floors exposed to sun and air, or better in rotating cylinders through which warm air passes. At a certain degree of dryness the parchment becomes brittle and breaks easily in the milling process, which thus removes the parchment envelope and silver skin from the seeds. In fact, the milling must be done while the parchment is still warm.

This milling is in many cases done in London and not in the country where the coffee is produced. Better preservation of shape and color of the bean has been observed when the latter is protected for a time by the parchment envelope. The cost of transportation is in this case a little higher, but it does not come into consideration, as from $2 to $3 more has been realized per hundredweight for coffee thus treated than for that cured in Central America.

In reviewing the so-called fermentation of coffee the conclusion is inevitable that alcoholic and acetic fermentations are not of direct benefit, but only indirect, inasmuch as heat is thereby produced which supports the action of a body (enzym) furnished by the bacteria, which dissolves the adhesive substance between parchment envelope and slimy layer.

○